Resource Inventory Notes

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MULTI-STAGE AND MULTI-PHASE SAMPLING

by

J.D. Nichols 1/

Historically sampling and estimation procedures have been misnamed and misused. One of the most abused of these terms is multi-stage sampling. As a result of several studies multi-stage sampling has taken on the connotation of any sampling and estimation procedure that calls on multiple levels of data to provide information.

Multi-stage sampling has a rather simple meaning.2/ The multi-stage sampling frame, Figure 1, consists of a list of sample units (Primary Sample Units)which are made up of smaller units (Secondary Sample Units), which are in turn made up of smaller units (Third Stage Sample Units). The number of stages and the size and number of sample units at each stage is dependent on the objectives of the inventory and the characteristics of the population to be sampled. The size and number of units may vary at each stage. The method of selecting a PSU, SSU and TSU for measurement depends on the objectives of the inventory and population characteristics. They can include simple random, variable probability and stratified selection.

The objective of multi-stage sampling is to provide a sample unit that can be cost efficiently measured and to cluster these samples in the higher level (larger) sample unit to reduce the travel cost between measurement units. The estimators for multi-stage sampling are well documented in several texts (see references) including Forest Mensuration, by B. Husch, C. Miller, and T. Beers.

1/ Owner, Resource Inventory Services, 650 Aram Ave, San Jose, Ca.

2/ Source: B. Husch, C. Miller, and T. Beers, Forest Mensuration, 2nd Edition, pages 219, 224, and 226.

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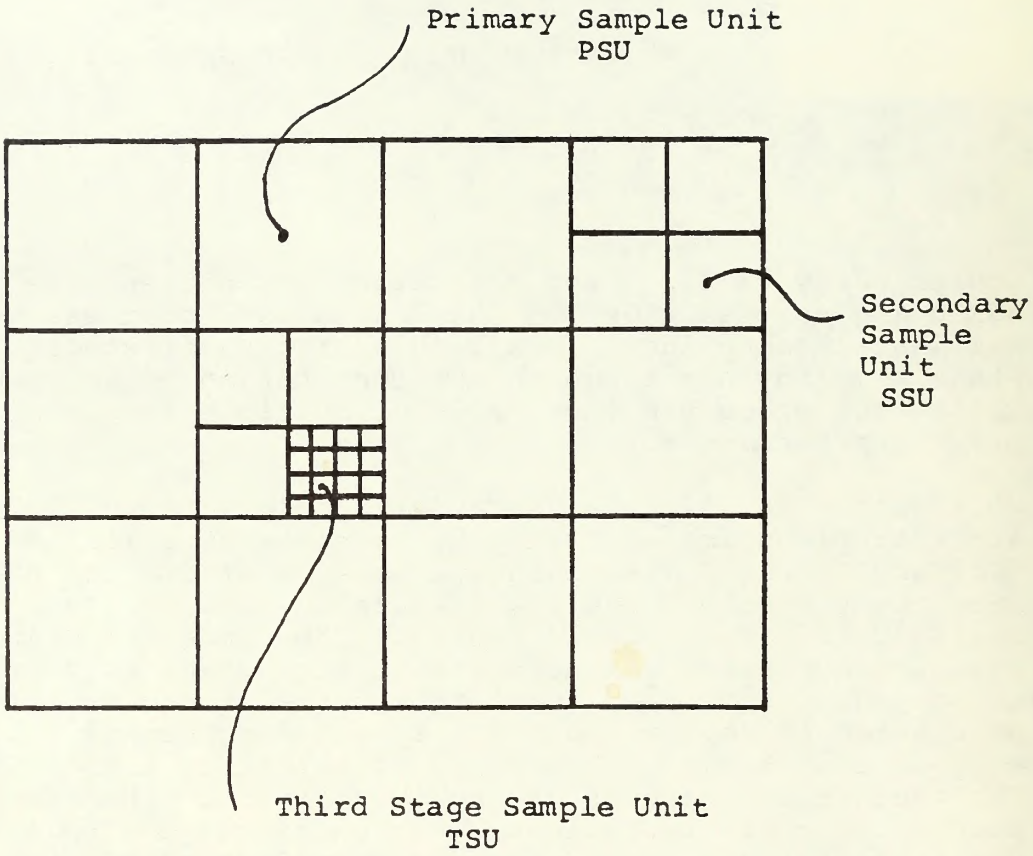

Figure 1: Hypothetical 3-stage multi-stage sample layout with equal size at each stage.

The optimization of a multi-stage design depends on the data collection cost, travel cost, between unit variability, and precision objectives. Given a two stage sampling frame the number of second stage samples is obtained from

$$n = \sqrt{\frac{C_1 S_W^2}{C_2 S_B^2}}$$

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n = optimum number of secondary units per primary unit.

C_1 = cost of establishing a primary unit.

C_2 = cost of establishing and measuring a secondary unit.

S_W^2 = estimate of variance within the groups of secondary sample units.

S_B^2 = estimate of the variance between the means of the secondary sampling units within the primaries.

Given a fixed budget, the number of primaries is

$$m = \frac{C}{C_1 + nC_2}$$

The points to be made are: 1) the optimization is dependent on cost and variance and 2) the procedure does not use multiple levels of data.

The sampling scheme that is most often confused and confounded with multi-stage sampling is multi-phase sampling (double sampling for two phases). Multi-phase sampling in general consists of selecting a large first phase sample of an auxiliary variable (x_i) which will provide a precise estimate of the primary variable (y_i). A subset of the first phase units are then selected and accurate measurements of the primary variable (y_i) are taken. In operational forest inventories this has included basal area (x_i) as an auxiliary estimator of timber volume (y_i) and aerial photo estimates of timber volume (x_i) as an auxiliary variable for ground measured timber volume (y_i). In range sampling a common practice is to make an ocular (professional) estimate of the weight of available forage (x_i) as an auxiliary variable for clipped, oven dry weight of the forage (y_i) on sample plots.

The procedure assumes that the observation of the x_is are paired (Figure 2) with the y_is, that there is a strong relationship between the x_i and the y_i, that the relationship can be estimated and that the x_i measurement is much less expensive to collect and process per sample than the y_i measurement.

The procedure to estimate the relationship between the y and x can take one of several forms. The form depends on the functional relationship between the x and y observation and the form of distribution of errors in estimating the y from x. An introduction to these principles and their associated estimators is contained in Elementary Statistical Methods For Foresters, Agriculture Handbook #317 (literature cited).

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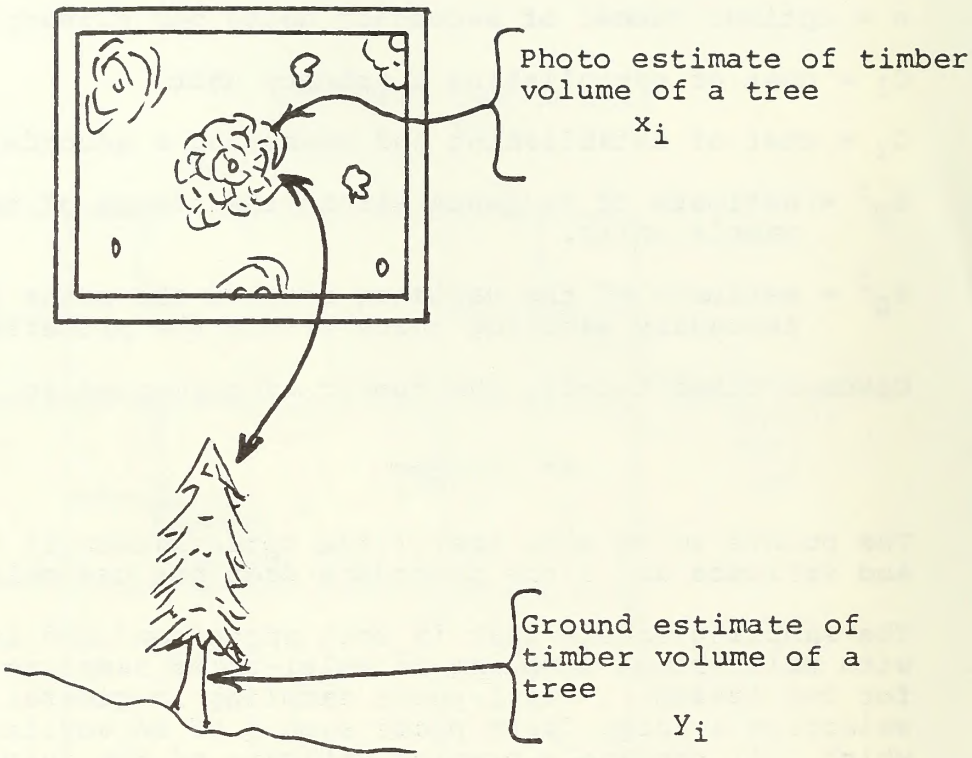

Figure 2; Multi-Phase Sampling

If conditions are such that a simple linear relationship exists between x and y, the ratio (λ) of the number of primary observations (n) to auxiliary observation (m) is estimated by the following. 3/

$$\lambda = \frac{n}{m} = \sqrt{\frac{1-\rho_{xy}^2}{\rho_{xy}^2}\,\frac{C_1}{C_2}}$$

ρ_{xy} = correlation between x and y.

C_1 = cost of obtaining and processing an observation of an auxiliary variable.

C_2 = cost of obtaining and processing on observation of the primary variable.

3/ L.C. Wensel, Wildland Resource Sampling (Draft), University of California, Berkeley, pages 4-75 to 4-79.

The total cost (C) of the collecting and processing of the inventory data is

$$C = C_1 m + C_2 n.$$

Therefore for a fixed budget

$$m = \frac{C}{C_1 + C_2 \lambda} \quad ; \quad n = m\lambda$$

The points to be made here are: 1) the allocation of effort in multi-phase sampling is a function of relative cost of the primary and auxiliary variable and 2) the strength of the relationship between the x and y observations (correlation for simple linear relationships). This is different than the multi-stage sampling procedure which depended on cost and variance rather than cost and correlation.

The above discussion of sample size has been restricted to fixed budget sample allocation. For procedures to optimize a given precision level, the reference by L.C. Wensel provides a good introductory discussion.

The two simple cases just describes are easily named. When multiple data levels and information extraction methods are used the sampling and estimation procedures become complex and the naming of the procedure becomes difficult. The sampling systems are combinations of multi-stage and multi-phase with multiple stratifications. Care must be taken to optimize the system and adequately describe the resultant sampling procedure, including the estimators of the characteristics of interest and the confidence bound for these estimates.

Literature Cited

B. Husch, C.I. Miller, and T. Beers; Forest Mensuration; 2nd Edition; The Ronald Press Company.

Freese, F.; Elementary Statistical Methods For Foresters; Agriculture Handbook #317; U.S. Department of Agriculture, Forest Service; Jan. 1967.

Wensel, L.C.; Wildland Resource Sampling (Draft); University of California, Berkeley; 1977.

Preliminary Pinon-Juniper Volume Tables

by

J. David Estola[1/]

ABSTRACT: This article contains pinon-juniper cubic-volume equations and tables (English and metric units) for northern New Mexico and south central Colorado.

Introduction

The Bureau of Land Management conducted extensive forest inventories in their Albuquerque and Socorro, New Mexico and Canon City, Colorado Districts in 1974. The inventories included the pinon-juniper forest type.

A total of 392 pinon pine trees (Pinus edulis Englm.) and 206 combined Rocky Mountain juniper trees (Juniperus Scopulorum Sorg.) and Utah juniper trees (J. osteosperma (Torr.) Little) were randomly selected and measured in the course of the inventory.

Pinon and juniper trees are found in a myriad of sizes and shapes varying from well formed single-stemmed trees to bushy multi-stemmed trees.

This extreme variation makes the task of developing accurate volume tables difficult.

The strategy used to build these cubic-volume equations and tables consisted of exploiting the following relationships:

1. diameter squared times height to predicted volume
2. crown diameter to volume variation within a diameter-height class
3. logarithmic volume equations and the least squares regression method to construct volume tables.

Field Measurement

A wide variety of site and tree attributes were collected in the extensive inventory.

1/ Forester, Bureau of Land Management, Denver Service Center (D-340), Denver Federal Center, Building 50, Denver, Colorado 80225

The following measurements were recorded and used to analyze certain tree attributes and cubic-volume relationships:

1. diameter stump height (outside bark at a one foot stump)[1/]
2. average crown diameter
3. total height (h)
4. tree segment[2/] diameter large end, diameter small end and length.

1/ A tree forking at or below one-foot was considered two or more trees; a tree forking above one-foot was considered one tree.

2/ A tree segment is defined as a piece of wood and bark at least 2 feet long and 2 inches in diameter outside bark. Length measurements were rounded to the nearest whole foot and diameters were rounded to the nearest whole inch. A segment could not have a crook or fork that offset more than 1/2 of the average diameter of the segment. Segmentation data was used to compute the cubic-volume of each sample tree.

Data Computation

Smalian's formula was used to compute the cubic-foot or cubic-metre volume of each segment.

Smalian formula:

$$V = \frac{B+b}{2} L$$

where:

V = cubic feet or metres volume
B and b = cross sectional areas of lower and upper bases, respectively, in square feet or metres
L = length in feet or metres

The total cubic volume of each sample tree is equal to the sum of its segments.

The logarithmic volume equation used to predict cubic-volume is

$$\log_{10}V=b_1\log_{10}(dsh^2xh)+b_2\log_{10}Cr+\log_{10}C$$

where:

V = cubic foot or metre volume
b_1 & b_2 = regression coefficients
dsh = diameter stump height
h = total height
Cr = crown diameter

① PIÑON PINE

FIGURE 1

② CUBIC VOLUME (Cubic feet)

INDIVIDUAL TREE VOLUMES INCLUDING ALL SEGMENTS TO A MINIMUM 2" DIAMETER AND 2' LENGTH

DIAMETER STUMP HEIGHT (In)	TOTAL HEIGHT 5(ft) CROWN DIAMETER					TOTAL HEIGHT 10(ft) CROWN DIAMETER					TOTAL HEIGHT 15(ft) CROWN DIAMETER					TOTAL HEIGHT 20(ft) CROWN DIAMETER					TOTAL HEIGHT 25(ft) CROWN DIAMETER					TOTAL HEIGHT 30(ft) CROWN DIAMETER					TOTAL HEIGHT 35(ft) CROWN DIAMETER					BASIS NO. OF TREES
	③ A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	
4	0.100	0.120	0.131	0.139	0.145	0.209	0.252	0.275	0.291	0.304	0.322	0.388	0.424	0.449	0.469	0.438	0.528	0.576	0.610	0.637	0.555	0.670	0.731	0.775	0.808											33
6	0.237	0.286	0.312	0.330	0.345	0.496	0.599	0.653	0.692	0.722	0.765	0.923	1.007	1.067	1.114	1.040	1.256	1.370	1.451	1.514	1.320	1.593	1.738	1.841	1.922	1.604	1.935	2.112	2.237	2.335	1.891	2.282	2.490	2.637	2.753	73
8	0.438	0.528	0.576	0.610	0.637	0.917	1.107	1.208	1.279	1.335	1.415	1.707	1.862	1.972	2.064	1.923	2.320	2.532	2.682	2.799	2.441	2.945	3.213	3.403	3.553	2.965	3.578	3.904	4.135	4.316	3.496	4.218	4.602	4.876	5.088	53
10	0.705	0.850	0.928	0.983	1.026	1.478	1.783	1.945	2.060	2.151	2.278	2.749	2.999	3.177	3.316	3.097	3.737	4.078	4.319	4.508	3.931	4.742	5.175	5.481	5.721	4.776	5.762	6.287	6.659	6.951	5.630	6.792	7.412	7.850	8.195	79
12	1.040	1.255	1.370	1.451	1.514	2.181	2.631	2.871	3.041	3.175	3.363	4.057	4.427	4.689	4.895	4.572	5.516	6.019	6.375	6.656	5.802	7.000	7.638	8.090	8.445	7.049	8.504	9.280	9.829	10.260	8.310	10.026	10.940	11.587	12.096	57
14	1.446	1.745	1.904	2.016	2.105	3.031	3.657	3.991	4.227	4.412	4.674	5.639	6.153	6.517	6.803	6.354	7.666	8.365	8.860	9.249	8.064	9.729	10.616	11.244	11.737	9.797	11.820	12.898	13.661	14.260	11.550	13.935	15.205	16.105	16.811	47
16	1.923	2.320	2.532	2.682	2.799	4.032	4.864	5.308	5.622	5.868	6.216	7.499	8.183	8.667	9.048	8.451	10.196	11.126	11.784	12.301	10.725	12.937	14.119	14.954	15.611	13.030	15.720	17.154	18.169	18.966	15.361	18.533	20.223	21.419	22.359	25
18	2.473	2.984	3.256	3.449	3.600	5.185	6.255	6.825	7.229	7.546	7.994	9.644	10.523	11.146	11.635	10.862	12.958	14.208	15.079	15.758	13.792	16.640	18.157	19.231	20.075	16.757	20.216	22.060	23.365	24.390	19.755	23.833	26.006	27.545	28.754	12
20						6.443	7.833	8.548	9.053	9.451	10.011	12.078	13.179	13.959	14.571	13.611	16.420	17.918	18.978	19.811	17.272	20.838	22.738	24.084	25.141	20.985	25.317	27.621	29.260	30.541	24.734	29.847	32.569	34.496	36.009	7
22						7.959	9.602	10.477	11.097	11.584	12.271	14.804	16.154	17.110	17.860	16.683	20.127	21.963	23.262	24.283	21.171	25.542	27.872	29.521	30.816	25.722	31.032	33.862	35.866	37.439	30.324	36.584	39.921	42.283	44.138	2
24						9.584	11.562	12.617	13.363	13.949	14.776	17.827	19.453	20.603	21.507	20.090	24.231	26.447	28.012	29.241	25.495	30.758	33.563	35.549	37.109	30.974	37.369	40.777	43.189	45.084	36.516	44.055	48.073	50.917	53.151	2
26											17.531	21.150	23.079	24.444	25.517	23.835	28.756	31.378	33.234	34.692	30.247	36.492	39.820	42.176	44.026	36.748	44.335	51.241	53.489	55.834	43.323	52.268	57.034	60.409	63.059	1
28											20.537	24.777	27.036	28.636	29.892	27.922	33.686	36.758	38.933	40.641	35.434	42.750	46.648	49.408	51.576	43.050	51.938	56.674	60.027	62.661	50.752	61.320	66.814	70.767	73.872	1
30											23.791	28.710	31.328	33.182	34.637	32.356	39.034	42.594	45.114	47.093	41.059	49.536	54.053	57.252	59.763	49.884	60.183	66.671	69.556	72.608	58.809	70.951	77.421	82.001	85.599	
32																					47.127	56.856	62.041	65.712	68.595	57.256	69.076	75.376	79.835	83.337	67.500	81.436	88.862	94.119	98.248	
34																					53.641	64.715	70.617	74.795	78.076	65.170	78.624	85.794	90.870	94.857	76.830	92.692	101.144	107.129	111.829	
36																					60.605	73.117	79.785	84.506	88.213	73.631	88.832	96.933	102.668	107.172	86.805	104.726	114.276	121.037	126.347	
BASIS	3	6				19	36	16	2	1	4	46	58	14	9	3	25	49	22	9		3	23	14	8			1	9	5	4			1		2	392

① VOLUME TABLE BASED ON DATA GATHERED FROM 392 TREES IN THE CAÑON CITY, COLORADO and ALBUQUERQUE, NEW MEXICO PIÑON-JUNIPER INVENTORIES CONDUCTED IN 1974

② CUBIC VOLUME = $\text{Antilog}_{10}\ [1.06779 \times \log_{10}(D^2 \times H) + (0.17084 \times \log_{10} C) - 3.10179]$; $R = .918$ WHERE: D = DIAMETER STUMP HEIGHT (1 FOOT STUMP), H = TOTAL HEIGHT, C = CROWN DIAMETER

③ MIDPOINT AVERAGE CROWN DIAMETER

A = 2.5 (ft)
B = 7.5
C = 12.5
D = 17.5
E = 22.5

AVERAGE CROWN DIAMETER RANGE

0-5 (ft)
5-10
10-15
15-20
20+

① JUNIPER

FIGURE 2

② CUBIC VOLUME (Cubic feet)

INDIVIDUAL TREE VOLUMES INCLUDING ALL SEGMENTS TO A MINIMUM 2" DIAMETER AND 2' LENGTH

DIAMETER STUMP HEIGHT (In)	TOTAL HEIGHT 5(ft) CROWN DIAMETER					TOTAL HEIGHT 10(ft) CROWN DIAMETER					TOTAL HEIGHT 15(ft) CROWN DIAMETER					TOTAL HEIGHT 20(ft) CROWN DIAMETER					TOTAL HEIGHT 25(ft) CROWN DIAMETER					TOTAL HEIGHT 30(ft) CROWN DIAMETER					TOTAL HEIGHT 35(ft) CROWN DIAMETER					BASIS NO. OF TREES
	③ A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	
4	0.106	0.103	0.102	0.101	0.100	0.230	0.223	0.220	0.219	0.217	0.361	0.351	0.346	0.342	0.341	0.491	0.484	0.477	0.473	0.470	0.637	0.620	0.612	0.607	0.603	0.781	0.760	0.750	0.744	0.739						13
6	0.262	0.255	0.251	0.249	0.248	0.567	0.551	0.544	0.540	0.536	0.891	0.866	0.855	0.848	0.843	1.227	1.194	1.179	1.169	1.162	1.674	1.631	1.612	1.599	1.590	1.928	1.876	1.852	1.837	1.825						25
8	0.497	0.484	0.477	0.473	0.470	1.076	1.047	1.034	1.025	1.019	1.691	1.645	1.625	1.611	1.601	2.330	2.267	2.239	2.220	2.206	2.988	2.908	2.871	2.847	2.829	3.662	3.563	3.518	3.488	3.466						34
10	0.817	0.795	0.785	0.779	0.774	1.770	1.722	1.700	1.686	1.675	2.781	2.706	2.672	2.649	2.633	3.832	3.729	3.681	3.651	3.628	4.914	4.782	4.721	4.682	4.652	6.022	5.859	5.785	5.736	5.701						27
12	1.221	1.194	1.179	1.169	1.162	2.657	2.585	2.553	2.531	2.515	4.176	4.063	4.011	3.978	3.953	5.754	5.598	5.528	5.481	5.447	7.379	7.179	7.088	7.029	6.985	9.042	8.797	8.686	8.613	8.559						28
14	1.730	1.684	1.662	1.648	1.638	3.747	3.646	3.599	3.569	3.547	5.888	5.729	5.656	5.609	5.574	8.114	7.894	7.794	7.729	7.681	10.405	10.123	9.995	9.912	9.858	12.749	12.405	12.247	12.145	12.069						16
16						5.046	4.910	4.847	4.807	4.777	7.929	7.715	7.617	7.553	7.506	10.927	10.631	10.497	10.409	10.344	14.012	13.633	13.461	13.348	13.265	17.170	16.706	16.494	16.356	16.259						19
18						6.561	6.384	6.303	6.250	6.211	10.310	10.031	9.904	9.821	9.760	14.208	13.823	13.648	13.534	13.450	18.220	17.727	17.502	17.356	17.247	22.325	21.722	21.446	21.267	21.134						10
20						8.298	8.074	7.972	7.905	7.856	13.040	12.687	12.526	12.422	12.344	17.969	17.483	17.262	17.117	17.010	23.043	22.420	22.136	21.951	21.814	28.236	27.472	27.124	26.897	26.729						8
22						10.263	9.985	9.859	9.776	9.715	16.127	15.690	15.492	15.362	15.266	22.223	21.622	21.348	21.169	21.037	28.498	27.728	27.376	27.147	26.978	34.920	33.976	33.545	33.265	33.067						10
24						12.460	12.123	11.969	11.869	11.796	19.579	19.049	18.808	18.651	18.534	26.980	26.250	25.918	25.701	25.540	34.599	33.663	33.236	32.959	32.752	42.395	41.249	40.726	40.385	40.133						7
26						14.894	14.491	14.307	14.188	14.099	23.403	22.770	22.482	22.294	22.154	32.251	31.378	30.981	30.722	30.529	41.358	40.239	39.729	39.397	39.150	50.677	49.306	48.682	48.275	47.973						
28						17.569	17.094	16.877	16.736	16.632	27.607	26.861	26.520	26.299	26.134	38.034	37.015	36.546	36.240	36.014	48.787	47.467	46.866	46.474	46.183	59.780	58.163	57.427	56.946	56.590						2
30											32.197	31.326	30.930	30.671	30.479	44.369	43.168	42.622	42.265	42.001	56.898	55.359	54.658	54.201	53.882	69.710	67.834	66.974	66.414	65.999						2
32											37.179	36.174	35.715	35.417	35.195	51.234	49.844	49.207	48.805	48.500	65.702	63.925	63.115	62.587	62.196	80.508	78.330	77.338	76.691	76.211						3
34											42.559	41.408	40.884	40.542	40.288	58.648	57.062	56.339	55.868	55.518	75.210	73.175	72.248	71.644	71.196	92.157	89.665	88.529	87.788	87.239						
36											48.343	47.038	46.440	46.051	45.763	66.618	64.816	63.995	63.460	63.063	85.430	83.119	82.066	81.380	80.871	104.681	101.850	100.659	99.718	99.095						2
BASIS	5	10	2			20	35	14	1		6	30	30	9	4	1	4	14	9	3		1	5	2	1											206

① VOLUME TABLE BASED ON DATA GATHERED FROM 206 TREES IN THE CAÑON CITY, COLORADO and ALBUQUERQUE, NEW MEXICO PIÑON-JUNIPER INVENTORIES CONDUCTED IN 1974

② CUBIC VOLUME = $\text{Antilog}_{10}\ [1.11462 \times \log_{10}(D^2 \times H) - (0.02496 \times \log_{10} C) - 3.08600]$; $R = .924$ WHERE: D = DIAMETER STUMP HEIGHT (1 FOOT STUMP), H = TOTAL HEIGHT, C = CROWN DIAMETER

③ MIDPOINT AVERAGE CROWN DIAMETER

A = 2.5 (ft)
B = 7.5
C = 12.5
D = 17.5
E = 22.5

AVERAGE CROWN DIAMETER RANGE

0-5 (ft)
5-10
10-15
15-20
20+

FIGURE 3

(1) PIÑON PINE

(2) CUBIC VOLUME (CUBIC METRES)

INDIVIDUAL TREE VOLUMES INCLUDING ALL SEGMENTS TO A MINIMUM 5.08 CM DIAMETER AND .61 M LENGTH

DIAMETER STUMP HEIGHT (CM)	TOTAL HEIGHT 1.5 (M) CROWN DIAMETER					TOTAL HEIGHT 3.0 (M) CROWN DIAMETER					TOTAL HEIGHT 4.5 (M) CROWN DIAMETER					TOTAL HEIGHT 6.0 (M) CROWN DIAMETER					TOTAL HEIGHT 7.5 (M) CROWN DIAMETER					TOTAL HEIGHT 9.0 (M) CROWN DIAMETER					TOTAL HEIGHT 10.5 (M) CROWN DIAMETER					BASIS NO. OF TREES
	(3) A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	
10	.003	.003	.004	.004	.004	.006	.007	.007	.008	.008	.009	.010	.011	.012	.013	.012	.014	.015	.016	.017	.015	.018	.020	.021	.022	.018	.022	.024	.025	.026	.021	.026	.028	.030	.031	33
15	.006	.008	.008	.009	.009	.013	.016	.018	.019	.019	.021	.025	.027	.029	.030	.028	.034	.037	.039	.041	.035	.043	.047	.049	.052	.043	.052	.057	.060	.063	.051	.061	.067	.071	.074	73
20	.012	.014	.015	.016	.017	.025	.030	.032	.034	.036	.038	.046	.050	.053	.055	.052	.062	.068	.072	.075	.066	.079	.086	.091	.095	.080	.096	.105	.111	.116	.094	.113	.124	.131	.137	53
25	.019	.023	.025	.026	.028	.040	.048	.052	.055	.058	.061	.074	.080	.085	.089	.083	.100	.109	.116	.121	.106	.127	.139	.147	.154	.128	.155	.169	.179	.187	.151	.182	.199	.211	.220	79
30	.028	.034	.037	.039	.041	.059	.071	.077	.082	.085	.090	.109	.119	.126	.131	.123	.148	.162	.171	.179	.156	.188	.205	.217	.227	.189	.228	.249	.264	.275	.223	.269	.294	.311	.325	57
35	.039	.047	.051	.054	.056	.081	.098	.107	.113	.118	.125	.151	.165	.175	.183	.171	.206	.225	.238	.248	.216	.261	.285	.302	.315	.263	.317	.346	.367	.383	.310	.374	.408	.432	.451	47
40	.052	.062	.068	.072	.075	.108	.131	.142	.151	.158	.167	.201	.220	.233	.243	.227	.274	.299	.316	.330	.288	.347	.379	.401	.419	.350	.422	.460	.488	.509	.412	.497	.543	.575	.600	25
45	.066	.080	.087	.093	.097	.139	.168	.183	.194	.203	.215	.259	.282	.299	.312	.292	.352	.384	.407	.425	.370	.447	.487	.516	.539	.450	.543	.592	.627	.655	.530	.640	.698	.739	.772	12
50						.174	.210	.229	.243	.254	.269	.324	.354	.375	.391	.365	.441	.481	.509	.532	.464	.559	.610	.646	.675	.563	.680	.741	.785	.820	.664	.801	.874	.926	.966	7
55						.214	.258	.281	.298	.311	.329	.397	.434	.459	.479	.448	.540	.589	.624	.652	.568	.686	.748	.792	.827	.690	.833	.909	.963	1.005	.814	.982	1.071	1.135	1.185	2
60						.267	.310	.339	.359	.374	.397	.478	.522	.553	.577	.539	.651	.710	.752	.785	.684	.826	.901	.954	.996	.831	1.003	1.094	1.159	1.210	.980	1.182	1.290	1.367	1.427	2
65											.471	.568	.619	.656	.685	.640	.772	.842	.892	.931	.812	.979	1.069	1.132	1.182	.986	1.190	1.298	1.375	1.436	1.163	1.403	1.531	1.621	1.693	1
70											.551	.665	.726	.769	.802	.749	.904	.987	1.045	1.091	.951	1.147	1.252	1.326	1.384	1.155	1.394	1.521	1.611	1.682	1.362	1.643	1.793	1.899	1.983	1
75											.634	.771	.841	.891	.930	.868	1.048	1.143	1.211	1.264	1.102	1.330	1.451	1.537	1.604	1.339	1.615	1.867	1.949	2.017	1.578	1.904	2.078	2.201	2.298	
80											.733	.884	.965	1.022	1.067	.997	1.203	1.312	1.390	1.451	1.265	1.526	1.665	1.764	1.841	1.537	1.854	2.023	2.143	2.237	1.812	2.186	2.385	2.526	2.637	
85											.834	1.007	1.099	1.164	1.215	1.135	1.369	1.494	1.582	1.651	1.440	1.737	1.895	2.008	2.096	1.749	2.110	2.303	2.439	2.546	2.062	2.488	2.715	2.875	3.002	
90											.943	1.137	1.241	1.315	1.372	1.282	1.546	1.687	1.787	1.866	1.627	1.963	2.141	2.268	2.368	1.976	2.384	2.602	2.756	2.877	2.330	2.811	3.067	3.248	3.391	
BASIS	3	6				19	36	16	2	1	4	46	58	14	9	3	25	49	22	9	3	23	14	8		1	9	5	4			1		2	392

1. VOLUME TABLE BASED ON DATA GATHERED FROM 392 TREES IN THE CAÑON CITY, COLORADO and ALBUQUERQUE, NEW MEXICO PIÑON-JUNIPER INVENTORIES CONDUCTED IN 1974
2. CUBIC VOLUME = $Antilog_{10}\ [1.06779 \times Log_{10}(D^2 \times H) + (0.17084 \times Log_{10} C) - 4.87518]$; $R = .914$ WHERE: D = DIAMETER STUMP HEIGHT (30 CM STUMP), H = TOTAL HEIGHT, C = CROWN DIAMETER
3. MIDPOINT AVERAGE CROWN DIAMETER
   - A = 0.75 (M)
   - B = 2.25
   - C = 3.75
   - D = 5.25
   - E = 6.75

AVERAGE CROWN DIAMETER RANGE
- 0 - 1.5 (M)
- 1.5 - 3.0
- 3.0 - 4.5
- 4.5 - 6.0
- 6.0+

FIGURE 4

(1) JUNIPER

(2) CUBIC VOLUME (CUBIC METRES)

INDIVIDUAL TREE VOLUMES INCLUDING ALL SEGMENTS TO A MINIMUM 5.08 CM DIAMETER AND .61 M LENGTH

DIAMETER STUMP HEIGHT (CM)	TOTAL HEIGHT 1.5 (M) CROWN DIAMETER					TOTAL HEIGHT 3.0 (M) CROWN DIAMETER					TOTAL HEIGHT 4.5 (M) CROWN DIAMETER					TOTAL HEIGHT 6.0 (M) CROWN DIAMETER					TOTAL HEIGHT 7.5 (M) CROWN DIAMETER					TOTAL HEIGHT 9.0 (M) CROWN DIAMETER					TOTAL HEIGHT 10.5 (M) CROWN DIAMETER					BASIS NO. OF TREES
	(3) A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	
10	.003	.003	.003	.003	.003	.006	.006	.006	.006	.006	.010	.009	.009	.009	.009	.013	.013	.013	.013	.013	.017	.017	.016	.016	.016	.021	.020	.020	.020	.020						13
15	.007	.007	.007	.007	.007	.015	.015	.015	.015	.014	.024	.023	.023	.023	.023	.033	.032	.032	.031	.031	.042	.041	.041	.040	.040	.052	.050	.050	.049	.049						25
20	.013	.013	.013	.013	.013	.029	.028	.028	.028	.027	.045	.044	.044	.043	.043	.063	.061	.060	.060	.059	.080	.078	.077	.076	.076	.098	.096	.094	.094	.093						34
25	.023	.022	.021	.021	.021	.048	.046	.046	.045	.045	.076	.073	.072	.071	.071	.103	.100	.099	.098	.097	.132	.128	.127	.126	.125	.162	.157	.155	.154	.153						27
30	.033	.032	.032	.031	.031	.071	.069	.069	.068	.068	.112	.109	.108	.107	.106	.155	.150	.148	.147	.146	.198	.193	.190	.189	.188	.243	.236	.233	.231	.230						28
35	.046	.045	.045	.044	.044	.101	.098	.097	.096	.095	.158	.154	.152	.151	.150	.218	.212	.209	.208	.206	.279	.272	.268	.266	.265	.342	.333	.329	.326	.324						16
40						.136	.132	.130	.129	.128	.213	.207	.205	.203	.202	.293	.286	.282	.280	.278	.326	.366	.362	.359	.356	.461	.449	.443	.439	.437						19
45						.176	.171	.169	.168	.167	.277	.269	.266	.264	.262	.382	.371	.367	.364	.361	.489	.476	.470	.466	.463	.600	.583	.576	.571	.568						10
50						.223	.217	.214	.212	.211	.350	.341	.336	.334	.332	.483	.470	.464	.460	.457	.619	.602	.595	.590	.586	.768	.746	.735	.729	.725	.938	.913	.901	.893	.888	8
55						.276	.268	.265	.263	.261	.433	.421	.416	.413	.410	.597	.581	.573	.569	.565	.765	.745	.735	.729	.725	.938	.913	.901	.893	.888						10
60						.335	.326	.321	.319	.317	.526	.512	.505	.501	.498	.725	.705	.696	.690	.686	.929	.904	.893	.885	.880	1.139	1.108	1.094	1.085	1.078						7
65						.400	.389	.384	.381	.379	.629	.612	.604	.599	.595	.866	.843	.832	.825	.820	1.111	1.081	1.067	1.058	1.052	1.361	1.324	1.307	1.297	1.288						
70						.472	.459	.453	.450	.447	.741	.721	.712	.706	.702	1.022	.994	.982	.973	.967	1.310	1.275	1.259	1.248	1.240	1.606	1.562	1.542	1.530	1.526						2
75											.866	.841	.831	.824	.819	1.192	1.159	1.145	1.135	1.128	1.528	1.487	1.468	1.456	1.447	1.873	1.822	1.799	1.784	1.773						2
80											.999	.972	.959	.951	.945	1.376	1.339	1.322	1.311	1.303	1.765	1.695	1.681	1.670	1.662	2.162	2.104	2.077	2.060	2.047						3
85											1.143	1.112	1.098	1.089	1.082	1.575	1.533	1.513	1.500	1.491	2.020	1.965	1.940	1.924	1.912	2.475	2.408	2.378	2.358	2.343						
90											1.298	1.263	1.247	1.237	1.229	1.789	1.741	1.719	1.704	1.694	2.294	2.232	2.204	2.186	2.172	2.812	2.735	2.701	2.678	2.661						2
BASIS	5	10	2			20	35	14	1		6	30	30	9	4	1	4	14	9	3		1	5	2	1											206

1. VOLUME TABLE BASED ON DATA GATHERED FROM 206 TREES IN THE CAÑON CITY, COLORADO and ALBUQUERQUE, NEW MEXICO PIÑON-JUNIPER INVENTORIES CONDUCTED IN 1974
2. CUBIC VOLUME = $Antilog_{10}\ [1.11462 \times Log_{10}(D^2 \times H) - (0.02496 \times Log_{10} C) - 4.97427]$; $R = .924$ WHERE: D = DIAMETER STUMP HEIGHT (30 CM STUMP), H = TOTAL HEIGHT, C = CROWN DIAMETER
3. MIDPOINT AVERAGE CROWN DIAMETER
   - A = 0.75 (M)
   - B = 2.75
   - C = 3.75
   - D = 5.25
   - E = 6.75

AVERAGE CROWN DIAMETER RANGE
- 0 - 1.5 (M)
- 1.5 - 3.0
- 3.0 - 4.5
- 4.5 - 6.0
- 6.0+

$\log_{10}C$=base 10 log of volume intercept value.

(b_1, b_2 and $\log_{10}C$ are obtained by regular least squares methods)

Results

Figures 1 through 4 are the resulting cubic-volume tables. Cubic-volume equations and r values are located below each table. Cubic-volume include wood and bark. Wood and bark in the stump and limbs less than 2 inches is excluded. (Refer to pages 7a and 7b for Figures 1 through 4).

Conclusions

Due to the extreme variation in pinon and juniper, a volume table based on three variables may not accurately state the volume of individual trees.

The Forest Service Intermountain Experiment Station at Ogden, Utah will soon publish gross cubic-volume tables for pinon-juniper in northern New Mexico. The Intermountain Station used a more complex regression analysis technique to screen many variables, combinations of variables and transformation of variables from a large number of samples to develop the tables. The tables will provide flexibility for estimating gross cubic volumes to varying top diameters (1 inch through 7 inches) for single and multi-stemmed trees.

The tables in this article were compared with an advance copy of the Forest Service tables for single-stemmed trees to a 2 inch top. Because the tables are constructed differently, a direct comparison was not possible. Generally, the tables compared favorably.

Though these tables may not provide accurate estimates of individual tree volumes, acceptable estimates can be achieved in northern New Mexico and south central Colorado for aggregations of trees.

Current Literature

Please order directly from addresses given.

General

"A Basic Inventory That Works" by Wendt in Rangeman's Journal 5(5):164-166, (Oct. '78) at your local conservation library.

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Ecological Land Classification Series No. 5, "Land/Water Classification" from Canada Committee on Ecological (Bio-Physical) Land Classification, Lands Directorate, Environment Canada, Ottawa K1A OH3.

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"Focus on Renewable Natural Resources" Vol. 4(1), from Forest, Wildlife & Range Exp. Sta., College of Forestry, Wildlife & Range Sciences, Moscow, ID 83843.

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FORESTRY

"Untersuchungen über die Bestandes-Massenermittlung durch die Deckpunkthöhensumme" by Prof. Masami Kitamura, Dept. of Forestry, Univ. of Yamagata, 1-23 Wakabamachi, 997 Tsuruoka, Japan.

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Forestry program for Oregon supplements No. 1 "Non-industrial Private Forest Management: An Action Recommendation" and No. 2 "Underproductive Forest Lands in the Oregon Coast Range" are available from State of Oregon, Dept. of Forestry, 2600 State Street, Salem, OR 97310.

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Tech. Note 323 "An Economic Analysis Series for Screening Proposed Timber Management Projects - Report No. 2 - Precommercial Thinning Only - Lodgepole Pine - Site Index 60" by Francis Horak. Drop us a line for a copy.

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Res. Paper PNW-235 "A Technique for Predicting Logging Residue Volumes in the Douglas-Fir Region"

Reprint "New Tools Allow Examination of Skyline Alternatives Speedily" by Burke.

Both from: Pacific Northwest Forest & Range Exp. Sta., P.O. Box 3141, Portland, OR 97208.

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Drop us a line for Tech. Note 319 "Intensive Forest Inventory - A Selected Bibliography" by Costello and Pettijohn. Also ask for "Allowable Cuts, Forest Regulation, Economics - A Bibliography" by H. Gyde Lund.

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Gen. Tech. Report PSW-24 "Tree Failures and Accidents in Recreation Areas: A Guide to Data Management for Hazard Control" from Pacific Southwest Forest and Range Experiment Station, P.O. Box 245, 1960 Addison Street, Berkeley, CA 94701.

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Reprint - "Advances in Information Systems and Services in the Forestry Community" by Dwinell.

Resource Bull. SE-43 "Coastal Virginia's Timber Resource - Trends, Present Conditions, and Opportunities for Improvement".

Resource Bull. SE-45 "Forestry Statistics for the Piedmont of South Carolina".

Res. Note SE-263 "Predicting Logging Residues for the Southeast".

Res. Paper SE-174 "Predicting Fire Behavior in Palmetto - Gallberry Fuel Complexes".

All from The Southeastern Forest Exp. Sta., P.O. Box 2570, Asheville, NC 28802.

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Booklet - "How To Examine Branches For Spruce Budworm Egg Masses" from Cooperative Forestry Research Unit, School of Forest Resources, Room 227, Nutting Hall, University of Maine, Orono, ME 04473.

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Bull. 664T "Preliminary Weight Yield Tables For Even-aged Upland Oak Forests", from Division of Forestry, West Virginia University, Morgantown, WV 26506.

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Bull. 16 "Full Forest Utilization - A Bibliography" from Forest, Wildlife and Range Exp. Sta., University of Idaho, Moscow, ID 83843.

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"Disc-Hammer Starter For Increment Borer" by Liu and Tang in Journal of Forestry, November '78, p. 732-733 at your local conservation library.

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Gen. Tech. Report RM-58 "Computing Average Skidding Distance For Logging Areas With Irregular Boundaries and Variable Log Densities" from Rocky Mt. Forest & Range Exp. Sta., 240 West Prospect Street, Ft. Collins, CO 80526.

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RANGE & WILDLIFE

"Comments on Browse Inventories in Louisiana" by Pearson & Sternitzke. Journal of Wildlife Management 42 (1):169-171 at your local conservation library.

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Contribution No. 165 "Evaluation of Streamside Bufferstrips For Protecting Aquatic Organisms" from Water Resources Center, University of California, Davis, CA 95616.

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Division Report #9 "Live Trapping and Handling Coyotes For Research" from Colorado Division of Wildlife, 6060 Broadway, Denver, CO 80216 - price $1.00.

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Misc. Paper #12 "Topography, Climate and Soil Types As Indicators of Fremont Regional Variation" from Museum of Natural History, Idaho State University, Pocatello, ID 83209 - price $1.00.

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Fritzner, R.E., L.E. Rogers and D.W. Uresk. 1977. "Techniques Useful For Determining Raptor Prey-Species Abundance". Raptor Res. 11(3): 67-71 at your conservation library.

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Wildlife Digest No. 11 "Using Chest Circumference to Determine Bear Weight" from Arizona Game & Fish Dept., 222 W. Greenway Rd., P.O. Box 9099, Phoenix, AZ 85068.

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Gen. Tech. Rept. RM-57 "Manual of Saltbushes (Atriplex spp.) in New Mexico"

Res. Paper RM-202 "Arizona Chaparral: Plant Associations and Ecology" from Rocky Mt. Forest & Range Exp., Sta., 240 W. Prospect St., Fort Collins, CO 80526.

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Ag. Handbook 511 "Cavity-Nesting Birds of North American" - for sale by Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price unknown.

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REMOTE SENSING

IAFHE RSL Res. Report 78-3 "Remote Sensing Analysis of the Vegetation of the Mississippi River Headwaters - Leech Lake, Minnesota"

IAFHE RSL Res. Report 78-4 "Remote Sensing Applications to Habitat Analysis of the Bering River - Controller Bay Trumpeter Swan Management Area and Martin River Valley, Alaska".

IAFHE RSL Res. Report 78-5 "Water/Vegetation Conditions on the Lower St. Croix River and on Mississippi River Pools 1-4 in 1939".

All from IAFHE Remote Sensing Lab., University Minnesota, College of Forestry, 1530 North Cleveland Ave., St. Paul, MN 55108.

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Reprint "Inventory of Land Use and Land Cover of the Puget Sound Region Using LANDSAT Digital Data" by Gaydos & Newland.

Reprint "Low-cost Computer Classification of Land Cover in the Portland Area, Oregon, by Signature Extension Techniques" by Gaydos.

Contact Land Information and Analysis Office, USGS National Center, Mail Stop 710, 12201 Sunrise Valley Drive, Reston, VA 22092.

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SOILS & WATERSHED

Reprint "A Two-Element Ceramic Sensor for Matrix Potential and Salinity Measurements" by Scholl.

Reprint "Some Measurement of Settlement in a Rocky Mountains Snow Cover" by Bergen.

Both From Rocky Mt. Forest & Range Exp., Sta., 240 W. Prospect Street, Ft. Collins, CO 80526.

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"Northwater" A Newsletter dealing with notes on Water Resources Research in Alaska is available free of charge from Northwater Editor, Institute of Water Resources, University of Alaska, Fairbanks, AK 99701.

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Meetings

Workshop on Remote Sensing Field Research - June 25-26 at Purdue University. scene characterization, spectral data acquisition and calibration, data analysis and instrumentation systems will be covered.

Machine Processing of Remotely Sensed Data - A symposium, June 27-29, 1979 at Purdue University. Emphasis will be on Research Results in:

1. Digital representation and understanding of remotely sensed scenes.
2. Utilization of digitally processed earth resource data.
3. Extraction of information primarily from digital remotely sensed earth resource data.

Remote Sensing Short Course - ongoing throughout the year at Purdue. The course is intended for individuals involved with the extraction of usable information from raw remote sensing data. The fee is $565.

For information on any of these meetings contact Purdue University, Laboratory for Applications of Remote Sensing, West Lafayette, IN 47907.

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Sampling on Successive Occasions - A workshop sponsored by Department of Forest and Wood Sciences, Colorado State University, S.A.F. Inventory Working Group and IUFRO S4.02-03 will be held July 17-20, 1979. The workshop is designed for resource managers and researchers engaged in sampling projects such as national and state timber surveys, multi-resource inventories, timber inventories on industry-owned lands, etc. A knowledge of basic sampling technique is assumed. The course will be limited to 40 people and will cover expected values, probability sampling, best linear unbiased estimates, independent estimates, remeasurement, sampling with partial replacement, optimum sample sizes and sampling on more than two occasions. The fee is $250. Contact Office of Conferences and Institutes, Residential Conference Center, Colorado State University, Fort Collins, Colorado 80523.

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Dynamic Similarities of Oceans and Atmospheres - is the theme of the Canadian Meteorological and Oceanographic Society XIII Congress. This will be held at the University of Victoria, Victoria, B.C., May 30-June 1. For details contact Dr. Richard Bennett, Resource Analysis Branch, Ministry of the Environment, Parliament Bldgs, Victoria, B.C., Canada V8V IX4.

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1979 Forest Inventory Workshop. Don't let the name fool you. This workshop is designed to appeal to land managers, inventory specialists, practitioners, data analysts and biometricians. This national meeting is sponsored by the SAF Inventory and Biometrics Working Groups, IUFRO Subject Groups S4.02 and S6.02 and by Colorado State University. Over 84 papers will deal with such subjects as Multi-Resource Inventories, Biometrics, Inventory Projection and Growth, Inventories on Successive Occasions, Sampling Techniques, Sampling Aspects of Aerial Photography, Computer Uses in Resource Inventories, Tropical Inventories, Biomass Measurement, Biomass Inventory, Metric Conversion Strategies, Product Estimation and a series of contributed papers. Registration fee will be about $75. The dates are July 23-26, 1979, at Colorado State University. For details contact Office of Conference and Institutes, Residential Conference Center, Colorado State University, Fort Collins, Colorado 80523.

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Remote Sensing for Natural Resources - An international view of problems, promises and accomplishments sponsored by the University of Idaho, IUFRO and SAF. Dates are September 10-14, 1979.

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Coming in 1980. Arid Land Resource Inventory - workshop sponsored by the Mexican Forest Service and the Society of American Forester's Inventory Working Group. Dates are November 30-December 6, 1980 and the place La Paz, Mexico. Watch the Notes for further details and plan to attend.

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Miscellaneous

SAF Inventory Working Group elects new officers for 1979 & 1980. Dave Bower of Weyerhaeuser is the incoming chairman, Skip House of Great Northern Paper Company is chairman-elect and Dr. Harry Wiant of West Virginia University is the new secretary for the 1100 member Working Group.

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Society for Range Management (SRM)forms Range Inventory Standardization Committee. The purpose is to promote uniform methodology and terminology for rangeland inventories and assessments. J. Kemmedson (Univ. of Ariz.) is the chairman. Other members include John Artz (Univ. of Nev.), Robert Barnes (SEA (ARS)), Richard Driscoll (USFS) Richard Eckert (SEA (ARS)), Floyd Kinsinger (BLM), George Knoll (BIA), Phil Ogden (Univ. of Ariz.), Don Pendleton (SCS), C.B. Rumburg (SCS) and Lamar Smith (Univ. of Ariz.).

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Wanted! Lead articles, current literature and meeting announcements for publishing in the "Notes". If announcing a meeting, please allow at least a four month lag time.

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